

PASSING **GOOD** JUDGMENT: ➡ ➡



Other nations
are
racing to improve their
nuclear weapons capabilities.



What can the U.S. do
to stay competitive?

INTRODUCTION

In the 1990s, with the Cold War over, the United States and the Soviet Union began reducing their nuclear arsenals and, along with other nations, signed the Comprehensive Test Ban Treaty (CTBT), agreeing to stop underground testing of nuclear weapons. The last U.S. nuclear test, “Divider,” took place in September 1992. (The United States Senate has not ratified the CTBT.)

In 1994 a new, science-based Stockpile Stewardship Program (SSP) replaced nuclear weapons testing as the way to assess the performance of the existing stockpile. The science part of stockpile stewardship would be the enabler. The U.S. weapons labs would undertake a variety of scientific studies using new specialized experimental facilities, advanced computer simulations of weapons performance, and extensive data analyses of past tests and of new nonnuclear experiments. These activities would

allow the existing weapons to be refurbished and assessed without the need for a nuclear test.

The SSP’s originator in the Department of Energy, Vic Reis, assistant secretary of energy for defense programs, saw the program as a hedge against an uncertain future. The stockpile was fine at the time, but who knew what the conditions would be in, say, 20 years? Whatever happened, a strong program of weapons-related science would preserve the stockpile. And it would preserve

Bob Webster (left) leads a discussion regarding the challenges faced by the Lab’s two generations of nuclear weapons designers in the Second Nuclear Age. The discussion was a main focus of the 2nd Los Alamos Primer lectures, held in honor of the Lab’s 70th anniversary. The first-generation weapons designers shown here on the opposite page are (right to left) Gary Wall, John Pedicini, and Jas Mercer-Smith. Continuing right to left, second-generation designers are John Scott, Langdon Bennett, and Brian Lansrud-Lopez. (Photo: Los Alamos)



the national weapons labs and their intellectual capabilities and knowledge, enabling them to do whatever was needed for the nation's deterrence, including rebuilding an arsenal should the need arise.

It is now 21 years since the last nuclear test and almost 20 years since the formal inception of the SSP. During those years, the world has changed. Instead of receding from the geopolitical stage, nuclear weapons are again coming forward, front and center, in the Second Nuclear Age. More nations have them, and more covet them as a possible means of increasing their security and their influence on international affairs.

To find out how prepared the labs are to face this newly dangerous world, *National Security Science* (NSS) interviewed LANL's most important nuclear stewards: the weapons designers themselves. Their job is to assess the nuclear warheads currently in the stockpile, plan and guide necessary changes in them, and design the steps that will help certify

their reliability, safety, and security. They advise the Laboratory director as he prepares his Annual Assessment Letter for the president of the United States regarding the four warhead types (B61, W78, W76, and W88) that Los Alamos is responsible for stewarding. They also brief the director of Lawrence Livermore regarding the weapons that laboratory has designed (B83, W80, W87). The designers must also be able to assess the threat posed by foreign nuclear weapon designs.

The materials presented here were compiled from those interviews and from the Designers Roundtable, which was held as part of the 2nd Los Alamos Primer lectures (July 2013). Part 1 is a discussion with three of LANL's still-active "first-generation" designers, those who participated in nuclear testing. Part 2 focuses on four of the "second-generation" designers, who came to Los Alamos after 1992 and therefore never took part in full-scale nuclear tests. ~



~Part 1: First-Generation Designers~

Jas Mercer-Smith, John Pedicini, and Gary Wall

Also participating: Associate Director for Weapons Physics Bob Webster

NSS: You're the last of that extremely rare breed: active scientists who have both designed a nuclear weapon and exploded it in a nuclear test at the Nevada Test Site (NTS). What were the days of nuclear testing like?

Gary Wall: I came to Los Alamos in the 1970s, during the height of the Cold War. Things were very hectic. We were doing experiments and trying to put weapons into the stockpile at a great rate. The Lab was detonating 12 to 16 nuclear tests a year, and each was preceded by 1 to 3 hydrotests. (See sidebar on next page.) The test site was very busy, and the pressure to build the equipment and move quickly from hydrotest to hydrotest or from hydrotest to nuclear test was intense.

Jas Mercer-Smith: NTS was chosen because of its proximity to Los Alamos. I remember taking the "Dash," which was a 2.5-hour nonstop flight from Los Alamos to NTS. You'd get on at 6:30 a.m. and land at Desert Rock in Nevada at 8 a.m. [gaining an hour with the time change], have all day to work, and come back at about 5 p.m. It was a great flight. In the morning you'd be flying over the Grand Canyon at 15,000 feet and the sun's rising. It was really pretty.

It was a heady experience, going out to NTS and making a huge hole in the ground with a test weapon you designed yourself. You may laugh, but designers are very fond of their holes. I remember sitting down with my daughter, bringing



"Mandrel-Pliers," a nuclear test conducted in August 1969. The photo shows the surface around ground zero collapsing several minutes after the test, forming a subsidence crater 350 feet wide and 50 feet deep. (Photo: Los Alamos)

Gary Wall has 42 years of experience in the design and analysis of weapon primaries. Wall was a member of design teams on 25 nuclear tests and the lead designer on another 7.

Jas Mercer-Smith came to Los Alamos in 1983. He has contributed to the design of six nuclear tests and was the lead design physicist for another three.

John Pedicini, who joined the Lab in 1981, worked on 13 nuclear tests and was lead designer on 3 of them.

Bob Webster presently oversees the portion of LANL that includes the Lab's weapons designers. Webster joined the Lab as a technical staff member in 1989. His weapons work was in code development and weapon physics. He has not worked as a weapons designer.

up NTS on Google Earth, and picking out my holes for her. My biggest one is about 1,300 feet across [about a quarter mile] and 130 feet deep.

It takes an impressive amount of energy to create a hole that big! Today I think we sometimes forget how powerfully destructive these weapons are because all we look at are computer simulations, the results of calculations. We never see a real test.

NSS: How did an underground test form a crater on the surface?

Mercer-Smith: In the test of a nuclear device, a "shot," the device was buried 1,000 to 2,000 feet underground to keep radioactive contamination from escaping. When the shot went off, it vaporized everything around it and formed a tremendous underground cavity. The rock and dirt on the surface naturally fell into the cavity and sealed in the radioactive debris, creating a "subsidence" crater.

John Pedicini: You would dig a deep hole, lower the bomb and the sensors to capture test results down the hole, and then backfill with cement. After the cement had cured, which could take weeks, we started the countdown to detonation. The other weapons designers and the military were watching all this, waiting for crater formation as proof of success. It could be up to two hours after the shot before the surface collapsed and you had a crater.

Wall: Given the kind of diagnostics we fielded, we were able to gather a lot of scientific information from the tests. The tests weren't just for shaking the ground, although being out there when the ground shook was exciting. The shock wave from the detonation moved the ground under your feet, so



Workers prepare for the last U.S. nuclear test, "Divider," a Los Alamos–designed shot that took place on September 23, 1992. Here, the Divider device is shown before being lowered into its test shaft. When the device was in place, the shaft was filled with layers of magnetite, sand, concrete, and epoxy to contain the bomb debris underground. (Photo: Los Alamos)

the power of the shot became a physical sensation in your body. It was exciting, especially when it was a big test, but it was also humbling and stressful.

Most tests were aimed at developing weapons for the stockpile—weapons that had to have very specific military-required characteristics such as size, weight, and explosive yield [energy release]. We had to predict the outcome, and we knew that Washington and our Department of Defense [DoD] customers would scrutinize the test results to see if we had screwed up.

The pressure for success—to predict things right or get a result that was even better than predicted—was so high that we tended to low-ball our predictions. We knew that producing a higher-than-expected yield would have a greater psychological impact than even nailing it exactly. On the other hand, if the yield was lower than predicted, there was tremendous pressure to explain what had gone wrong and to do a better job of designing and predicting next time.

Mercer-Smith: You might think of testing as precise, white-lab-coat work, but that's not how it really was. I have a story. It goes back to 1962–1963, near the end of atmospheric testing in the Pacific and to the way things actually worked. People at the Lab were going through the data from these last shots, and the head of the radiochemistry group says they've got an anomaly in the radiochemistry data; they've got a whole bunch of arsenic, and they can't figure out how the fission process could result in so much arsenic. He says we don't understand this, and it's important to figure out what happened.

Nuclear Weapons and Hydrotests

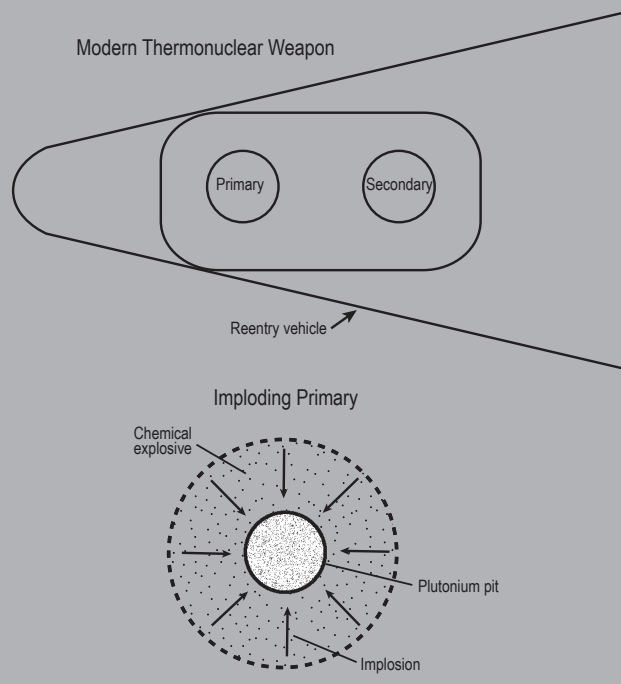
Modern thermonuclear weapons have two stages: the primary and the secondary. The primary, which is a fission bomb, delivers energy to the secondary, which uses both thermonuclear fusion and fission to release hundreds to thousands of times more energy than a fission bomb alone.

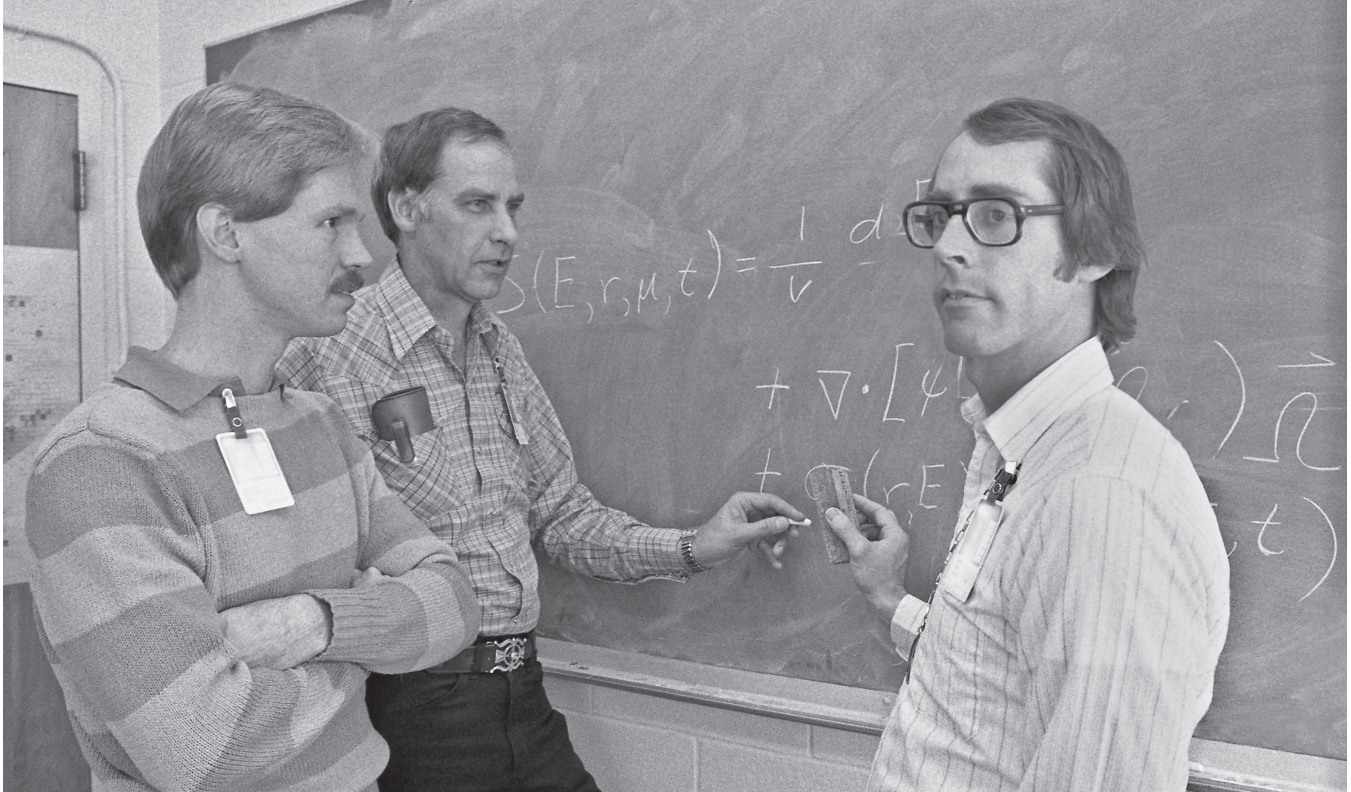
The nuclear core of the primary is a sphere of plutonium or enriched uranium and is known as the pit. Chemical explosives surround the pit and when detonated, send shock waves inward, squeezing (imploding) the pit from a subcritical to a supercritical mass—one that will sustain an uncontrolled nuclear fission chain reaction, ending in a nuclear explosion.

The radiation from this nuclear explosion is transferred to compress and ignite the thermonuclear fuel in the secondary. The entire process, from detonation of the explosives in the primary to the release of fusion and fission energy in the secondary, happens in less than a thousandth of a second.

What Are Hydrotests?

Hydrotests are the most common experiments that scientists do to study the implosion of the primary. To keep the hydrotest nonnuclear, they replace the plutonium in the pit with a surrogate heavy metal such as depleted uranium or lead. The explosively generated high pressures and temperatures cause some of the materials to behave hydraulically (like a fluid), hence the name *hydrotest*. During the experiment, scientists collect data on the symmetry and compression of the imploding pit by taking x-ray images.





Gary Wall (right), circa 1984 (Photo: Los Alamos)

Then Tom Scolman, who was test director later, when I joined the Lab, starts laughing and says, “I think I may have an explanation. We had a severe rodent problem on the island. And since it was the last shot, we just stuck all the leftover rat poison on the barge with the bomb and blew it up!”

Now that story’s not written down anywhere, but that’s what happened. I wonder if the arsenic was ever explained in the test data.

NSS: Who made all the decisions for a shot?

Wall: There was a design team for a shot, made up of three to four designers and a lead designer, who acted as both the team leader and mentor.

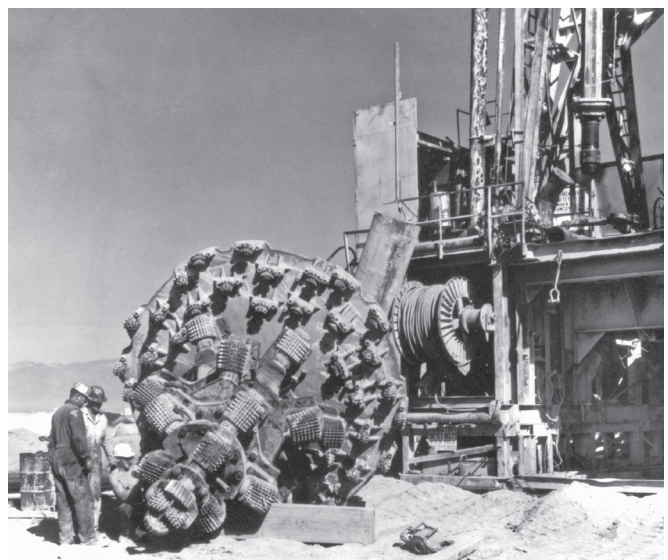
Pedicini: Actually, we had relatively few lead designers—people who could design something completely new, who could respond to the military’s request for a new weapon that could do a specific mission never before done by an existing weapon. In the old days, to be a lead designer, you had to prove yourself. You had to design the new device and “go public” with it—tell the military and weapons-design communities what the device would do—then go to Nevada, set it off, and see if your judgment was right or wrong. The lead designer was the person who was responsible for the outcome, whether it was a mistake or a success.

NSS: How long did it take to become a lead designer?

Pedicini: It could happen very quickly during the Cold War. In 1980, when I started at Los Alamos, I was 24, and by the time I was 25, I was a weapons design physicist. I fired my first nuclear test, called “Mini Jade,” at 26. A year later I designed and tested a “clean-sheet” design, a device that was a completely new concept. The Lab was using New Mexico

place names for its shots at the time; mine was “Vermejo” for Vermejo Park. It made a nice crater.

Mercer-Smith: I came to the Lab in 1983. At that time young designers would follow senior people around for the first two years. They wouldn’t let us touch anything because we’d just hurt ourselves. And after three or four years, they’d let us do something just to see if we messed up. After five years, if you hadn’t messed up, maybe they’d trust you with a shot. I was an apprentice for three years and was on the team for three very successful nuclear tests. At the end of those three years, I had my own shot to design. This was the training process: designers learned by doing. And after a decade you kind of knew how things worked.



Drill bit for drilling a large nuclear test emplacement hole. Drilling time could require as much as 12 weeks of around-the-clock work, depending on the hole’s location, depth, and diameter. Large shots required a hole on average 1,000–2,000 feet deep and up to 12 feet in diameter. (Photo: Los Alamos)

Wall: I was the lead designer on seven nuclear tests, and like everyone else here, I learned the trade on the job. It wasn't something you could learn in graduate school. A beginning designer would join a design team and work under the mentorship of the lead designer. Relatively quickly, the newcomer would be assigned to work on major hydrotests, and as his judgment developed from hands-on experience, he would be assigned to work on nuclear tests.

Eventually, if warranted, the developing designer got to be the lead in the design of a new weapon, and the test at NTS was the tangible feedback mechanism for developing and demonstrating judgment. Post-shot analyses of the test data allowed you to see which of your predictions were right, which were wrong, and why they were wrong. The test data also helped you evaluate the computer simulations that led to your predictions and learn which parts of the simulations you could trust and which you couldn't. Learning from these tests is what built credibility and judgment.



Gary Wall, today. An avid marathoner, Wall runs along the road up to Pajarito Mountain Ski Area. The Laboratory is seen in the background. (Photo: Los Alamos)

NSS: People in the Weapons Program talk about “designer judgment” as if it’s something out of the ordinary. Why?

Pedicini: Weapons design is based on an incomplete science, so designing weapons requires using a great deal of intuition. It's largely an art form. There isn't a set of blueprints or a set of complete equations available for building new weapons. In the absence of a full set of data, designers have to make decisions based on their experience and intuitions—judgments—to create new weapons. Weapon primaries are particularly complex, where the link between one physical process and another is still unknown, so we regularly have to rely on our gut feelings. We're not accountants who have exact numbers and can easily see when column A does not equal column B. We have only partial data on these extremely complex systems.

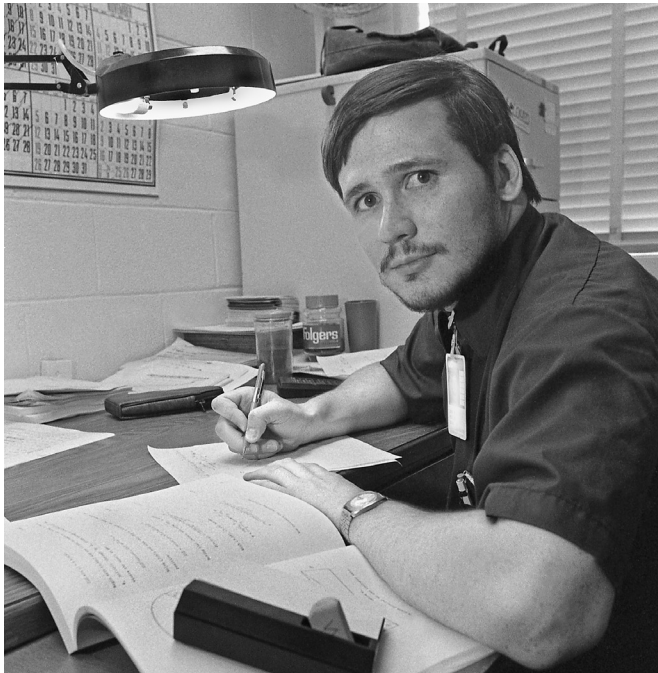
For that reason, it's typically a judgment call as to what would work in a primary design and what wouldn't. For instance, if you wanted to save weight and space and use the least amount of plutonium but still needed to meet the military requirement for a yield of, say, at least 100 kilotons, how much plutonium would you use? And what other warhead components could you change—and by how much—and still get the desired yield?

The test data helped you learn which parts of the simulations you could trust and which you couldn't.

In a system as complex as a nuclear weapon primary, every change could produce the “butterfly effect.” In chaos theory a small change in one part of the system, the “flap of a butterfly's wings,” could set in motion a series of events with enormous unpredictable consequences. We know this can happen in weapon designs because we've made changes in them, and the consequences in our test results sometimes really surprised us.

The act of designing a weapon primary involves making lots of compromises, and the consequences can't be known with 100 percent accuracy. If you change one thing, it needs to be balanced with some other change to ensure you get the desired result. That second change will need balancing too, and so on. That balancing act is performed in your head, and that's “judgment.”

A nuclear test challenged the accuracy of your judgment. Weighing the results of the test against your predictions—what you thought was going to happen—was how you developed better judgment.



John Pedicini, circa 1983 (Photo: Los Alamos)

In the absence of testing, that's the kind of judgment we're failing to develop today in our young designers.

Mercer-Smith: Here's an example of how judgment works. We use plastic-bonded high explosives in weapon primaries. The high explosives age along with the rest of the weapon. So will small defects in the aged plastic bonding change the explosives' performance?

Think about what happens with a car. When you get a new car, that new car smell is the plastics outgassing. Well, plastic-bonded high explosives outgas too, and that changes their structure: they'll develop cracks. If you have an old car, you'll notice that the dashboard cracks. Are the cracks in the 20-year-old plastic-bonded high explosives going to change the weapon's performance, safety, or security? In the absence of testing, a designer is going to need good judgment to answer that question.

And when we talk about designer judgment, that judgment is not due to the designer alone. A designer has to be an entrepreneur in the sense of knowing a little bit about everything and when some problem needs an answer from an expert, knowing who in the Laboratory is that expert.

Pedicini: I tell the young designers that any weapons designer worthy of the title has a large Rolodex filled with names of experts in a wide range of fields. Then when there's some really hard design question or a measurement problem or a puzzle about a test result, the designer knows whom to call for the best information available. We work in a national laboratory with a broad array of scientific talent available for consulting. It's imperative that a designer access that talent.

NSS: Since no new weapons are being designed or tested, do we still need "designer judgment" today?

Bob Webster: While we're not designing new weapons, other countries are. We need to anticipate what types of designs might be out there, what threats they pose, and how to do forensics [a nuclear-blast postmortem] on them should they ever be used. It takes a weapons designer with good judgment to do that kind of thinking. We can't afford to be surprised by our adversaries' capabilities.

Also, at some point the United States may decide it needs to modify its weapons to meet new challenges, such as improving safety and security features in the stockpile. The Second Nuclear Age is defined by more players wanting to become—and becoming—nuclear powers (see "The Second Nuclear Age," p. 2). Every nuclear nation is modernizing its nuclear capabilities. Our nation needs designers with good judgment to answer the call whenever it comes.

NSS: You're saying that designer judgment will be needed in the future, but what about today? Is it needed in the life-extension programs, the LEPs?

Pedicini: In most of the LEPs funded so far, we're doing "oil and lube jobs." You take out the warhead, you look for broken parts, you replace those, and you put the warhead back together. We did that on the W87 to bring it back as much as possible to new condition. We did that on the W76, and now we're doing it on the B61.

We also do hydrotests on the designs of the warheads' primaries, and those experiments are crucial for reassuring the military and ourselves that we're delivering a product that meets the specs. But those hydrotests don't really test designer judgment. There are no surprises. The designer does the hydrotest on, say, a refurbished old design and then compares the results with old test data. So the designer has almost nothing new to study or interpret. That doesn't exercise designer judgment.

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with good judgment to answer the call
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Webster: That may be true right now, but some of the LEPs planned for the future involve bigger changes, such as the ones having to do with increased safety and security. Also, the weapons in our nuclear stockpile were designed to last 10 years but are now 20 to 30 years old, and the materials continue to age and need replacement. As we continue to replace aging materials with new materials that are slightly different than the original ones and remanufacture parts using different processes than were used before, the differences between the refurbished weapons and the original

designs will increase. So each time a new LEP is proposed, the weapons designers must judge which changes are necessary and then develop a route to certify—and reassure our military, adversaries, and our allies—that our “life-extended” weapons will still perform, if and when needed, according to their design specifications.

Mercer-Smith: It’s up to the weapons designers to assess whether a defect we find during surveillance needs to be addressed and if so, how. That takes judgment. [In surveillance, weapons are drawn out of the stockpile and examined.] Even small defects or changes in a system like a weapon or a rocket can lead to catastrophic results. Judging how an aged weapon with a defect will or won’t perform is even more difficult than designing a brand-new weapon, where you work with known quantities and qualities.

Experimental data are essential for developing our ability to judge when, where, and how much the codes are lying.

Webster: Today, we’ve still got a few designers who developed their judgment in the era of nuclear testing and who can weigh in on these decisions. But LEPs call for extending weapon lifetimes for at least a couple more decades. By then the designers with test experience will be gone, and the people responsible for certifying our weapon systems will be those who have just entered the Lab force today. Will this new generation be up to the task?

Concerns about what our future designers will or won’t know are reflected in the Annual Assessment Letter our director sends to the president. The nature of the letter has evolved. Originally, it addressed, “Do you need to do a nuclear test, and is the stockpile safe, secure, and reliable?” More recently, as we respond to questions about the adequacy of the science-based tools and methods being used in stockpile stewardship, we also address the question, “Are we training the next generation of stewards?”

Are we giving the new designers the training and experience needed to qualify them for certifying a stockpile 20 years from now? I’m worried that because we’re doing very few experiments, we’re becoming much too dependent on computation alone. So when a new question comes up, I might hear the new designers say, “Well, let’s just compute it.” If that’s the only tool they have, I don’t think that’s good enough.

NSS: What’s the problem with relying so much on computer simulations?

Mercer-Smith: It’s important to remember that a computer code of a million lines is nothing more than a series of thousands of approximations. If any of those approximations aren’t valid, then the probability of error is significant. We use experiments to determine which of the approximations can be expected to be valid.

New designers sometimes expect too much from a computer code. When I joined the Lab, it was pounded into our heads over and over that the *codes always lie* and that the job of a designer is to know when, where, and how much. The key challenge for the future is to train the next generation so they have that kind of judgment.

But today we’re forgetting—or ignoring—that the codes can lie, and we don’t always have the experimental data we need—the reality check we need—to prove or disprove our conjectures. Experimental data are essential for developing our ability to judge when, where, and how much the codes are lying.

Webster: We’re not doing enough experiments to replace the loss of full-scale testing. What we’re talking about here is the need for more *integrated* experiments, which are experiments on weapon subsystems. Integrated experiments are the hydrotests we do at DARHT [Dual-Axis Radiographic Hydrodynamic Test facility] and the subcritical experiments we do at the Nevada National Security Site. Subcritical experiments, by definition, use plutonium, but not enough to ever produce a critical mass.



John Pedicini, today (Photo: Los Alamos)

NSS: Why are integrated experiments so important?

Webster: An integrated experiment gives us data about, for example, how an aging primary works. With full-scale nuclear testing forbidden, integrated experiments let us check the subsystems that make up the whole system, and from that we can infer the weapon's overall quality.

Integrated experiments also give us the data needed to validate the predictions of our computer codes and help us improve the codes. Then we can validate or refine the improved codes with further experiments. It's a constant cycle.

Without new experiments, we'll fail in the role of deterrence.

First, the designer runs a simulation that predicts the results of an integrated experiment. The experimental results then either validate the simulation and the prediction or not. The order, prediction first and integrated experiment second, is crucial because human beings can rationalize things faster than we'd like to believe. If the experiments came first, they would color how we read the results of a simulation. We'd always correctly predict the results of an experiment after the fact. Peer review also has its limitations because people can get into groupthink and be fooled by it. The only protection against rationalization and groupthink is doing experiments, new ones where the answer isn't already known.

NSS: So without testing, integrated experiments are the key to developing designer judgment.

Wall: That's right. Compared with the number of predictions we have to make using the codes, we aren't doing enough integrated experiments to back the codes up. There are too few hydrotests, and even fewer subcrits. Right now we're annually doing maybe four or five major hydrotests involving a full-up replica of a weapon primary.

We ought to be doing one hydrotest per month. If the resources were there, we could easily conduct that many experiments and feed those data back into improving both the weapons codes and designer judgment. In the testing era we were doing several hydrotests per month.

Today, there's so little experimental feedback to validate or contradict their predictive work that the new designers have a hard time maintaining interest. Some want to either become managers or drop out of the program. Sadly, that makes sense, but it's not what the nation's national security needs.

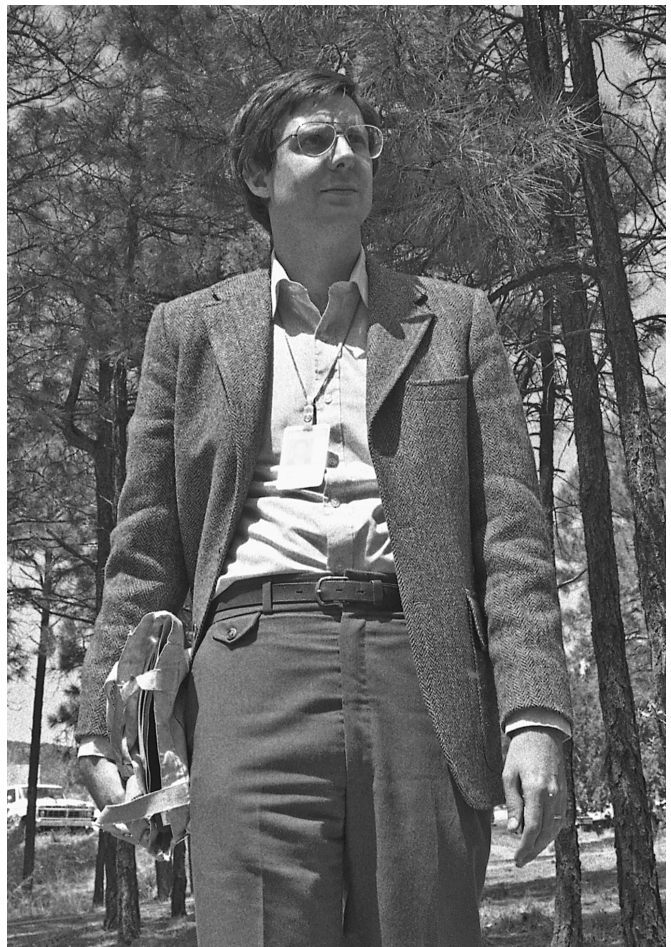
NSS: Would doing more experiments help in recruiting new designers?

Wall: That's one of the benefits of doing more experiments that's often overlooked. Maintaining the stockpile is a

long-term effort extending decades into the future. It would definitely be easier to recruit people to be designers if we were doing more experiments. I know this from my own experience and from conversations with the younger designers. You can do computer simulations over and over again, but without having the excitement of anchoring your results in reality, what's the point? Having the data from experiments, having that feedback, creates excitement. Those experiments could be new designs, but they also could be old designs analyzed with new diagnostics that give you more information than you had in the past. That's exciting too.

Gathering data is what keeps scientists excited, and the more experiments they do, the more scientists we can keep excited and interested in becoming designers.

Pedicini: Judgment comes from design experience: designing new weapons and new experiments. But we do very little actual designing now. Most of our integrated experiments don't test new designs, where you can make a mistake and learn from that mistake. Without new experiments, in which we can test ourselves and run the risk of a failed experiment, we'll fail in the role of deterrence. We need to accelerate the pace of trying new things and be willing to make some mistakes.



Jas Mercer-Smith, circa 1984 (Photo: Los Alamos)



Jas Mercer-Smith (left) at the Designers Roundtable (Photo: Los Alamos)

I'm not talking about experiments that just refine old designs. I'm talking about big-picture experiments, integrated experiments on new ideas that are going to reveal if our designers can handle the stress they'll be under in a world that may re-occur in the future. We had a testing moratorium in 1958–1961, and everybody thought, "Hey, the arms race is over!" Then the Russians shot a whole pot full of bombs in one week, and we were off to the races again.

We're in the second moratorium now, but what happened before could happen again. And if it does, the requirements of the stockpile will change. We'll need people who have been hardened a little bit—who have made mistakes and have developed their judgment and kept it sharp. Lack of judgment in designers will be fatal. We'll do things without using the judgment that experience brings, wasting time and resources and risking a catastrophic failure.

Here's an example. The Germans had a first-class navy in World War I, but then the Treaty of Versailles shut down their production for 20 years. When they later built the Bismarck-class battleships, the largest battleships ever built by Germany, they made major mistakes in design judgment. They made the ships very hard to sink but left the rudders unprotected and easy to disable. The British locked up the Bismarck's steering gear with a small torpedo. Also, the ship's main communications were above the armor belt, so an 8-inch shell destroyed them. These were major flaws in design judgment coming from a long span of inactivity in warship design. We run the same risk if we fail to challenge our designers continuously.

Webster: It's the same with students. If students can find their physics problems all worked out in the back of the textbook, they never turn in bad homework assignments. You have to give them problems without already-known answers if you want to know if your students are really thinking.

NSS: You mean the next-generation designers need to be challenged with new problems.

Pedicini: Yes. We should throw design challenges at them and make them do something new. They need to be learning, through as many experiments as necessary, if their design decisions are right or wrong. They need to be taking risks, and by that, I mean they have to risk failure, risk being wrong. You can't just keep doing what's been done before.

The weapons in our stockpile were developed for the world that existed during the Cold War; they're not necessarily the appropriate warheads for whatever comes next. You have to have the appropriate design staff, using good judgment, so that if the world changes, if we go back into another Cold War and we need a different set of weapons, we'll have the people who are capable of designing them.

Of course the new designs they do now won't go into the stockpile. But the judgment they're developing *will* go into the stockpile someday. It's the capital on which we'll build the future.



Preparations for an underground test at NTS. (Photo: Los Alamos)

NSS: If experiments are so important, why are so few being done?

Webster: Cost is a big issue. As experiments become too expensive, we have to shoot them much less often. Then scientists make more diagnostics to cram into each shot because they're worried that they will have only that one shot to get the data they need. This makes the experiments even *more expensive* and even *less frequent*. It's become a vicious cycle.

Pedicini: There's always going to be some cost associated with being competent, honest, and safe about how you do business. But that doesn't account for anything like the cost increases we've had. It seems to me that most of the money for our experimental program is spent on bureaucracy. We're going to have 10 people checking the checkers who are



Bob Webster moderating the Designers Roundtable. (Photo: Los Alamos)

checking the checkers who are checking the one guy doing the job. How about train the one guy properly, give him the discretion, treat him like a professional, and get rid of all these layers of bureaucracy?

Money's also being wasted by too much "project management." It's become a profession and a "thing" in and of itself, as opposed to being a means to reaching a goal. We should manage a project so it gets done the best way possible, not just manage for the sake of managing.

Wall: I think our infrastructure has aged to the point that it also affects how much money can be used for experimentation. Since the end of the Cold War, there hasn't been a driver for getting new, more-efficient, more-capable, more-cost-effective machinery to make and assemble parts. There hasn't been any urgency because we're not putting new things into the stockpile. Now that we're doing life-extension programs, we're putting a lot of money into maintaining our aged facilities and outdated manufacturing equipment—infrastructure that hasn't kept up with the times. So by postponing investment to save money yesterday, we made everything in the nuclear weapons complex more expensive today.

Pedicini: The fear of taking risks is another problem. Both in Washington and at the labs there's a growing tendency to foster a totally risk-averse environment. We've become so risk averse because our customers, like the National Nuclear Security Administration [NNSA] and the DoD, expect everything to be a success.

We must allow people to try things that might fail. It's also how you move forward. It's the people who are willing to risk their reputations who drive us into the future. We need to try things that might fail.

I'll give you an example from a recent hydrotest we did on a brand-new design that used high explosives [HE] in a new way. I needed help from an HE physicist, and Dan Hooks offered to help. I asked him right off if he was willing to fail. I said, "This may not work. The entire theory of high explosives and all the codes in the world say it won't work, but they're

valid only in a very narrow range, and we'll be stepping outside that range. Are you willing to try something that everyone will tell you won't work? And if it turns out not to work, will you be able to handle the failure?"

He was willing, and the hydrotest was a great breakthrough. It was stunningly good: it actually *exceeded* the implosion quality of anything we've seen before. But we wouldn't have even tried the experiment if Dan hadn't been willing to get dirty. And by "getting dirty," I mean run the risk of failure.

I was a designer on 13 nuclear tests, and I learned more from the one that didn't work so well than I learned from all the others.

Wall: I agree. A successful experiment proves what you already know; it validates your knowledge. In contrast, a failure, a missed prediction or a bad judgment call, lets you know where you need to seek more knowledge, where you need to go in order to expand your understanding.

There was fear of failure during the nuclear testing era too, but it was different. There wasn't *time* to explore riskier approaches that might have resulted in better weapons. The military wanted to put things into the stockpile as quickly as possible during the Cold War. We had a blank check to do that as long as we delivered the product on time.

In my current work, which focuses on understanding the effects of aging, especially plutonium aging, in the stockpile, the risk aversion is about high safety and security costs. The budget is fixed and plutonium science is very expensive—and it keeps going up, largely due to overblown safety and security costs, I think.

We're going to have 10 people checking the checkers who are checking the checkers who are checking the 1 guy doing the job.

Mercer-Smith: The problem is how do we balance, say, the small probability of an accidental release of radiation against the national security requirement that we maintain a nuclear stockpile? There is no incentive for the regulators to approve an experiment because if there were an accident, they'd be held accountable. The only way to absolutely guarantee that you won't have an accident is to *do nothing*. However, it's important to understand that doing nothing also represents a risk—a risk to national security.

We're not saying cut corners and be reckless. We're saying we need to better balance the costs and benefits of doing more experiments: manage the risks better.

Webster: In the National Academy of Sciences' 2013 report ["The Quality of Science and Engineering at the NNSA National Security Laboratories"], they said a very similar thing: "All experimental activities have inherent risk, and successful organizations manage that risk." But the labs have been

“focused too much on the safety risks of doing experiments with hazardous materials, rather than considering the risk of not doing them at all.” Not doing those experiments, they warned, risks our ability to do stockpile certification down the road, “which could increase the risk to national security.”

Wall: It's true that risk aversion about safety is being overdone to the point that it's interfering with getting our work done. The epitome of that is at the Lab's Plutonium Facility, where the safety rules have caused severe limitations on the quantity and speed of the work. And aging plutonium is the material we *most* need to work on in stockpile stewardship.

Mercer-Smith: Beryllium and high explosives also need more research, and doing experiments with these hazardous materials has also become prohibitively expensive because of increasingly stringent safety requirements.

Aging plutonium is the material we most need to work on in stockpile stewardship.

Wall: It's also true that doing so few experiments has led to a downsizing of the complex and a reduction in the number of people who make the parts we need for experiments. Without experiments, there's no driver for attracting those kinds of highly skilled people.

NSS: All these barriers—rising costs, fear of failure, increasingly stringent safety requirements, and risk aversion—mean not enough experiments are getting done and people are leaving. What can be done to increase experimentation?

Webster: We're trying to be more cost effective and break the cycle of doing fewer and fewer experiments that are more and more expensive by adopting a new approach. We're telling people, “We're going to do the shot on this date, and here's the schedule. We've got this budget, and with this budget we can shoot this many times. Make your diagnostics fit because the shot's going to fly on that date whether your diagnostic is there or not.” We're trying to get people to think about the costs and use some ingenuity.

Another key factor needed for doing more experiments is garnering not just NNSA and DoD support, but Lab-wide support. Many of the components of Weapons Program experiments aren't specifically about weapon design but rather are concerned with fundamental physics questions. How our physicists respond to help us increase experimentation will be important. And they're doing very well at proposing clever ways of doing diagnostics and coming up with things to measure. Our Operations and Business Directorate is going to have to get engaged too and help us back away from total risk aversion and instead embrace risk management, that is, let us take prudent risks. This will be successful only if the entire enterprise, both NNSA and the Lab, pulls together.

NSS: What is the most pressing experimental need now, and are there plans to meet that need?

Wall: The pressing need now is to learn how aging plutonium affects the stockpile. It's been argued that the plutonium pits in the stockpile will last 100 years, but there's no universal agreement on that. We haven't done enough experiments to know. Manmade plutonium hasn't even existed for 100 years. [Plutonium is made in nuclear reactors, the first of which was Enrico Fermi's “Pile.” It went critical in 1942.] In the interest of national security, it behooves us to do more experiments on plutonium to find out whether the claim of 100 years is true or not.

We can steward the stockpile almost indefinitely if we're doing the right homework. But right now, without more work on plutonium, I don't think we're doing the right homework.

Pedicini: But there's something new on the horizon that will allow us to do the needed work on plutonium. The neutron-diagnosed subcritical experiments now being proposed could help us study the properties of aged plutonium during implosion and explore the possibility of reusing older pits. [See Neutron-Diagnosed Subcritical Experiments p. 34]

This new kind of subcrit will also be a real training ground for new designers. They'll be designing experiments, predicting outcomes, and measuring things that have not been measured in 20 years. It will be a real opportunity for trying things that can fail and for honing judgment. If these new subcrits get approved, we'll be seeing the next generation of designers carrying this out.



Preparations for the “Praetorian-Rousanne” nuclear test, 1981. The crane (background) is for lowering the nuclear device, along with a rack of diagnostic sensors for monitoring the explosion, into the test shaft. The trailers (foreground), stationed at a safe distance from ground zero, contain instruments to record the sensors' diagnostic data, carried to the trailers by the miles of cables shown here snaking between them and the test. (Photo: Los Alamos)

NSS: If you had a chance to tell the Congress, the DoD, and taxpayers about why weapons designers are key to deterring a nuclear war, what would you say?

Wall: What weapons designers do is not so much maintain the stockpile as maintain deterrence. For deterrence to work, stewardship must be working. Stewardship works only if you have good weapons designers in hand.

So far, stewardship has been most successful in the theoretical and computational areas. It has been less successful in the experimental areas. Ultimately, preservation of the stockpile depends on weapons designers and their exercise of good judgment, learned through experimentation.

Pedicini: I'm afraid the Lab is becoming just an old library of ancient nuclear secrets, a monastery for the last few nuclear monks. But the nation has to have weapons designers who possess good judgment so if the world changes and we go back into another Cold War, we'll have the talent ready to go.

That's what we have to focus on: How do we develop that judgment? With experiments, that's how. But under the current constraints, we're not experimenting enough. We have an obligation to the taxpayers of this country to develop

new weapons designers with good judgment. But we're not being given the opportunity to meet that obligation.

Mercer-Smith: Sometimes when I'm giving a talk, I end by reading a passage from Mark Twain's *A Connecticut Yankee in King Arthur's Court*. The main character is a very good engineer who goes back in time to the fifth century and totally redoes King Arthur's England. He introduces things like electricity.

At the end of the book, there's a civil war. The engineer and his allies are surrounded by tens of thousands of knights, and he sends them this message: "We know your battle skills. We number 54. Fifty-four what, men? No. Minds. The most capable minds in the world; a force against which mere animal might cannot prevail."

Well, the mass of knights attacks. But knights on horseback do very poorly against the Gatling guns, poison gas, explosives, and electrified fences devised by the 54.

The reason we need new designers is not just to maintain the stockpile but to make sure the nation is never in the position of being like knights on horseback against Gatling guns. ✦

~ NSS Editorial Staff



The Nevada Test Site (now the Nevada National Security Site) was where most U.S. nuclear weapons were tested from 1951 to 1992. Of the more than 1,000 nuclear detonations done in Nevada (some tests had more than one detonation), over 900 were underground. The site covers more than 1,300 square miles. (Photo: Los Alamos)